2016 STATE OF THE LAKES UPDATE

CRYSTAL LAKE

REPORT DESCRIPTION

This report is an update on the health of Crystal Lake based on water quality data collected from 1994 through 2016 by local volunteers and Snohomish County Surface Water Management (SWM) staff. For additional background on the information provided here or to find out more about Crystal Lake, please visit www.lakes.surfacewater.info or call SWM at 425-388-3464.

LAKE DESCRIPTION

Crystal Lake is a private 50-acre lake located south of Maltby adjacent to the King County line. The lake has a maximum depth of over 9 meters (30 feet) and an average depth of about 4 meters (13 feet). The watershed, which is the land area that drains to the lake, surrounding Crystal Lake is large—almost 2100 acres, which is over 40 times the size of the lake. There is a 115-acre wetland immediately north of the lake. This wetland was originally part of a larger Crystal Lake, but has become vegetated over thousands of years. The body of the lake is surrounded by a gated community consisting of approximately 68 homes clustered around the lake shore. The Crystal Lake homeowners' association incorporated as Crystal Lake, Inc. and is active in managing the lake.

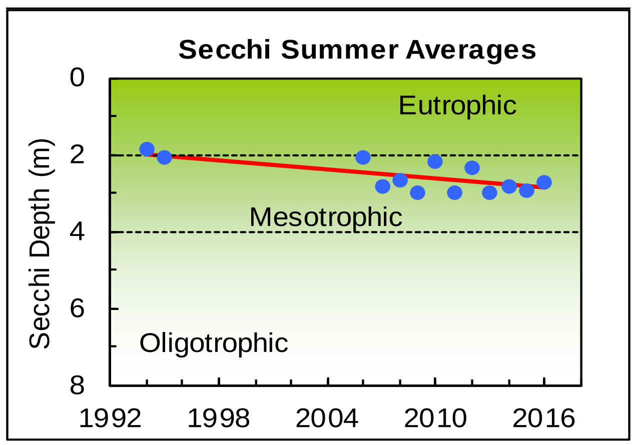
LAKE CONDITIONS

The following graphs illustrate the summer averages (May through October) and trend lines (shown in red) for water clarity, total phosphorus, and chlorophyll *a* for Crystal Lake. Please refer to the table at the end of the report for long-term averages and for averages and ranges for individual years.

Water Clarity

The water clarity of a lake, measured with a Secchi disk, is a reading of how far one can see into the water. Water clarity is affected by the amount of algae and sediment in the lake, as well as by water color. Lakes with high water clarity usually have low amounts of algae, while lakes with poor water clarity often have excessive amounts of algae.

The water clarity in Crystal Lake is low to moderate, partly because of the naturally dark color of the lake water. The long-term summer average water clarity is 2.6 meters (8.5 feet). Although there were no summer readings from 1996 through 2005, there have been enough measurements in recent years to show a statistically significant trend toward improving water clarity in Crystal Lake (p=0.05). Because of the data gap, this trend should be viewed cautiously. If water clarity is improving, this may be a result of less algae growth (although this is not consistent with the increasing chlorophyll *a* levels described below).



Water Color

The color of lake water affects water clarity and the depths at which algae and plants can grow. In many lakes, the water is naturally brown, orange, or yellow. This darker color comes from dissolved humic compounds from surrounding wetlands and does not harm water quality. Measurements of true water color provide clues to changes in water clarity. True water color is only the color from dissolved materials and not of the color of algae or sediment suspended in the water.

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The water color of Crystal Lake averaged 46 pcu (platinum-cobalt color units) in 2010-2011. This indicates a moderate amount of color in the lake water and is a slight increase from the 1994 – 1995 average of 40 pcu. Darker water should result in less algae and poorer water clarity. However, this is at odds with the trend toward better water clarity and the increasing trend in chlorophyll *a* described below.

Temperature

The temperature of lake water changes with the seasons and varies with depth. During spring and summer, the sun warms the upper waters. Because warmer water is less dense, it floats above the cooler, denser water below. The temperature and density differences create distinct layers of water in the lake, and these layers do not mix easily. This process is called stratification and occurs during the warm months. The warm, upper water layer is called the epilimnion. The colder, darker bottom zone is called the hypolimnion. These layers will stay separated until the fall when the upper waters cool, the temperature differences decrease, and the entire lake mixes, or turns over.

Temperature profile data taken during 2016 show that Crystal Lake was warming up in April and was strongly thermally stratified from May through October (see graph). This means that there was a large temperature difference between the warm upper waters and the cool bottom waters, and mixing did not occur between these layers. The upper waters reached their peak in temperature in August at 76°F (25°C) and then cooled down in September and October. At the same time, bottom water temperatures changed only a little and remained around 44°F (6 - 7°C). In fall, the surface waters continued to cool until the temperatures were equal from top to bottom. As stratification weakened, the lake water turned over (or mixed). The lake will stay mixed during the winter until springtime, when the upper waters begin to warm again.

Dissolved Oxygen

Oxygen dissolved in the water is essential for life in a lake. Most of the dissolved oxygen comes from the atmosphere. Like temperature, dissolved oxygen levels vary over time and with depth. During the warm months, the upper waters receive oxygen from the atmosphere, but the lower waters cannot be replenished with oxygen because of the separation between water layers. Meanwhile, bacteria in the lake bottom are consuming oxygen as they decompose organic matter. Eventually oxygen is depleted in the bottom waters. Low dissolved oxygen in the bottom waters can lead to a release of nutrients from the lake sediments.

The depth profiles of dissolved oxygen measured in 2016 largely correspond to the temperature profiles seen during that time period (see graph). In April and May, dissolved oxygen was lower in the bottom waters than near the surface. By June there was little or no oxygen below about 23 feet deep. Then, each month the zone of low oxygen expanded until there was very little dissolved oxygen below 10 feet deep. In addition, in May and June, there was a persistent pattern of lower dissolved oxygen around 10 to 15 feet deep coupled with a small increase in oxygen immediately below that depth. The reasons for this phenomenon may be slow settling and decomposition of organic matter, an abundance of zooplankton (microscopic animals) at this depth, and/or the shape of the lake bottom which causes much of the organic decomposition to occur at this depth.

During the stratified summer period, oxygen in the lower waters is consumed by the decomposition of organic material within the lake. Since the lake is strongly stratified, the oxygen is not replenished by the overlying oxygen-rich upper waters or by the atmosphere. When dissolved oxygen levels are near zero, phosphorus is often released from the sediments into the lake. This phosphorus can feed future algae blooms. In the fall and winter when the lake is mixed, dissolved oxygen is replenished throughout the entire lake.

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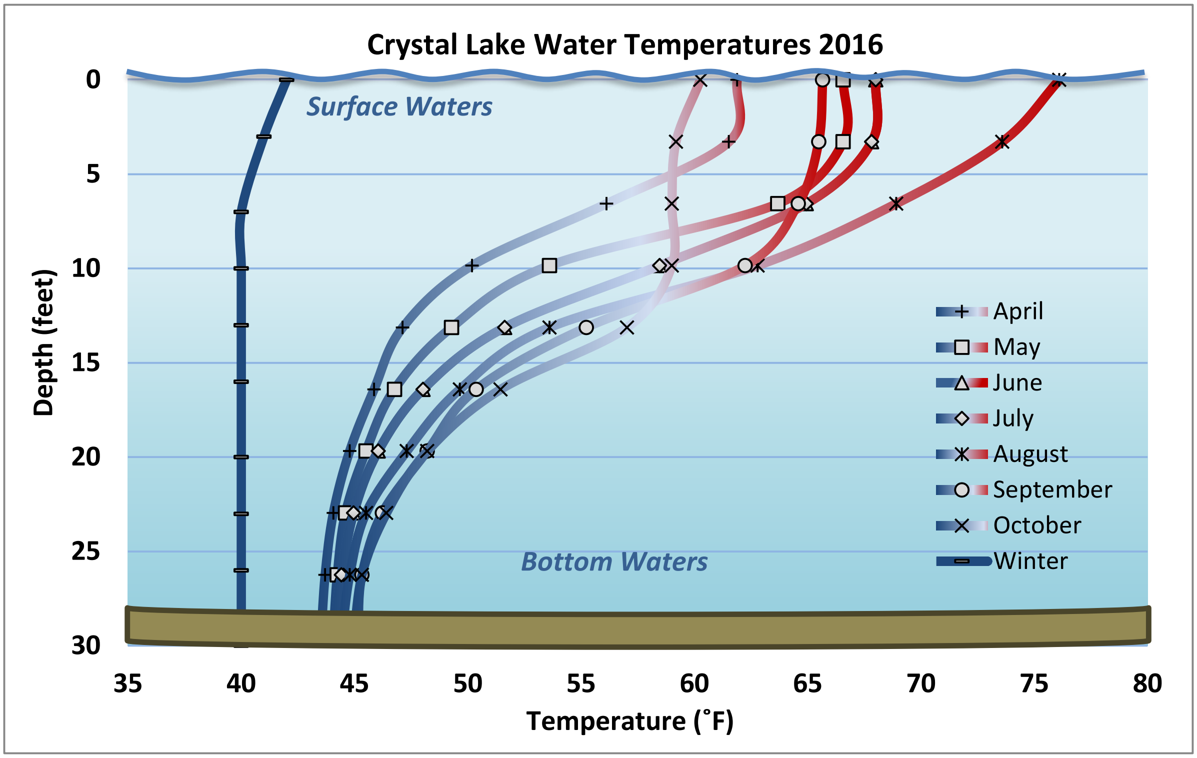
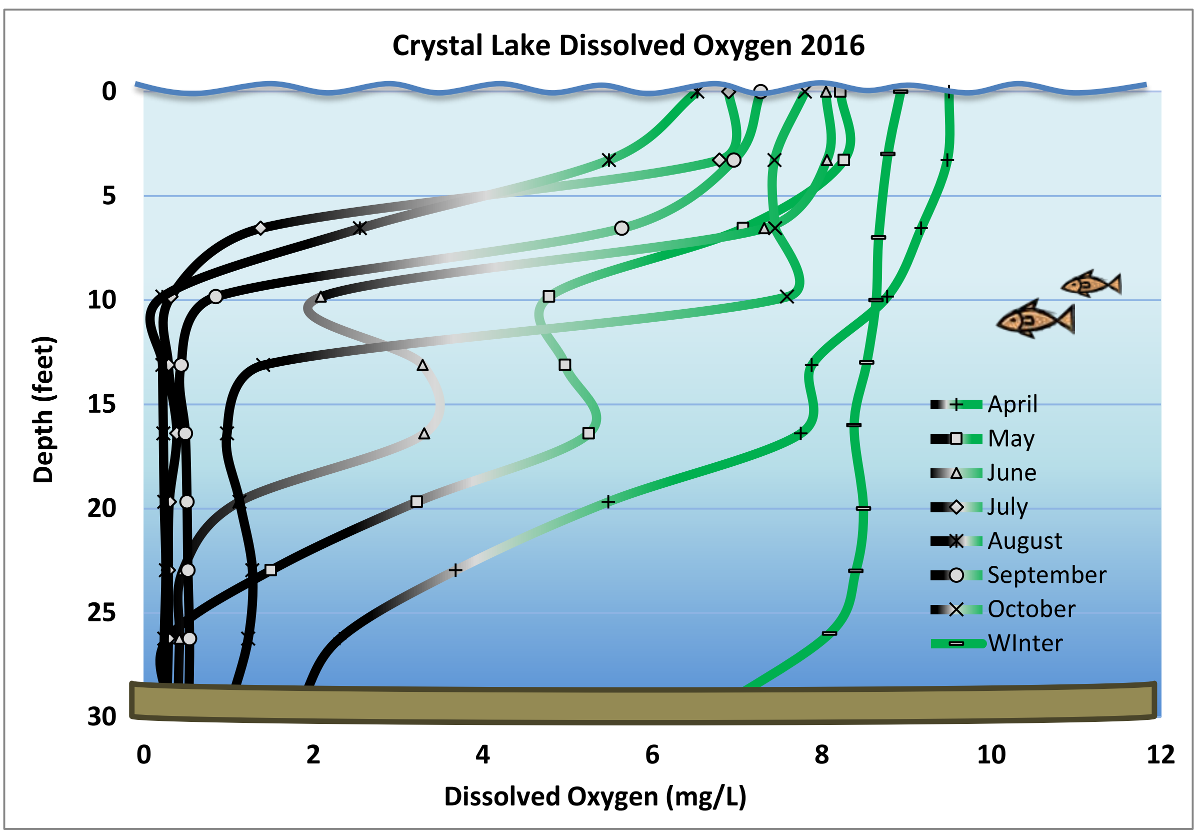
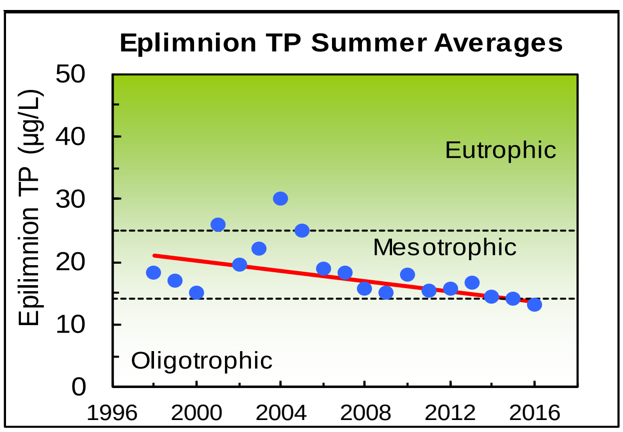




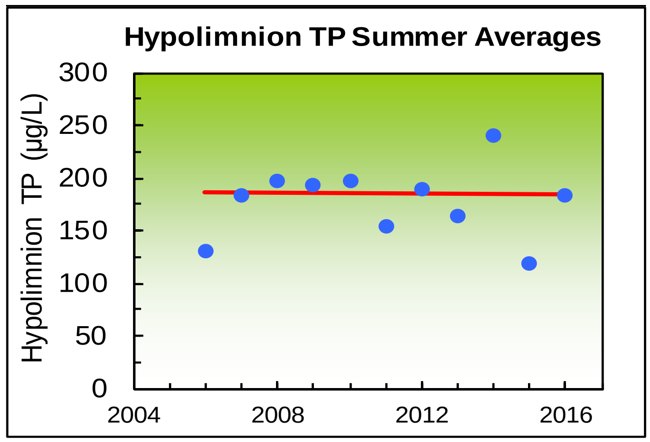
Phosphorus (key nutrient for algae)

Nutrients are essential for the growth of algae, fish, and aquatic plants in a lake. However, too many nutrients, especially phosphorus, can pollute a lake and lead to unpleasant algae growth. Nutrients enter the lake through stormwater runoff or from streams flowing into the lake. Sources of nutrients include fertilizers, pet and animal wastes, poorly-maintained septic systems and erosion from land clearing and construction. The principal nutrient of concern in Crystal Lake is phosphorus. Monitoring of phosphorus levels over time helps to identify changes in nutrient pollution.

In the epilimnion (upper waters) of Crystal Lake, the total phosphorus levels are moderate, with a 1998 – 2016 long-term summer average of 18 µg/L (micrograms per liter, which is equivalent to parts per billion). The annual averages were higher and more variable from 2001 through 2005, but in recent years have been lower and similar to levels in the late 1990s. One reason for this variability may be that there were only one or two measurements each summer from 1998 through 2005. Overall, between 1998 and 2016, there has been a statistically significant trend toward lower total phosphorus levels in the upper waters ($p=0.00$).



Total phosphorus concentrations in the hypolimnion (or bottom waters) are high. The 2006 – 2016 long-term summer average is 177 µg/L. The 2015 summer average was lower than previous years (119 µg/L), this may be the result of samples taken at a shallower depth due to lower lake levels. The 2016 summer average (184 µg/L) was similar to the long term average. Although the concentrations appear to be higher in some years, there is not a clear trend toward increasing phosphorus levels in the bottom waters. High phosphorus in the bottom waters is the result of a build-up of phosphorus released from the bottom sediments and any increases can be a warning sign of accelerating eutrophication.



Examining the pattern of phosphorus concentrations year round provides clues to the dynamics occurring in the lake. The graphs on the following page illustrate the average and the range of phosphorus concentrations year round for both the upper waters and bottom waters from 2006 through 2016. Phosphorus concentrations in the upper waters show moderate levels from late winter through the end of the summer. Then, in the fall and winter, phosphorus levels rise as the lake mixes and brings up the high phosphorus concentrations from the bottom waters. The inflow from streams also contributes to higher phosphorus levels in the rainy period beginning in November. The 2016 results followed this overall pattern.

Phosphorus levels in the bottom water are much higher than the upper waters and follow an opposite pattern. Concentrations rise to very high levels during the summer as phosphorus is released from the lake sediments during the period of low dissolved oxygen.

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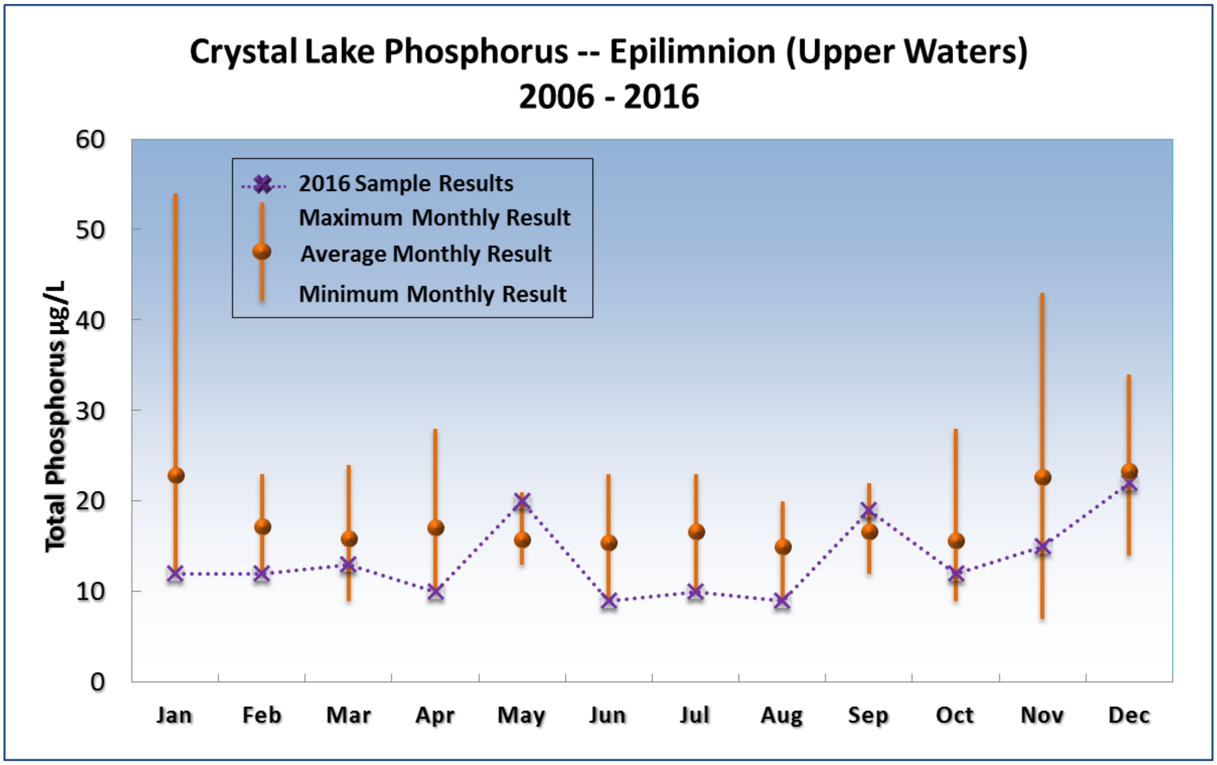
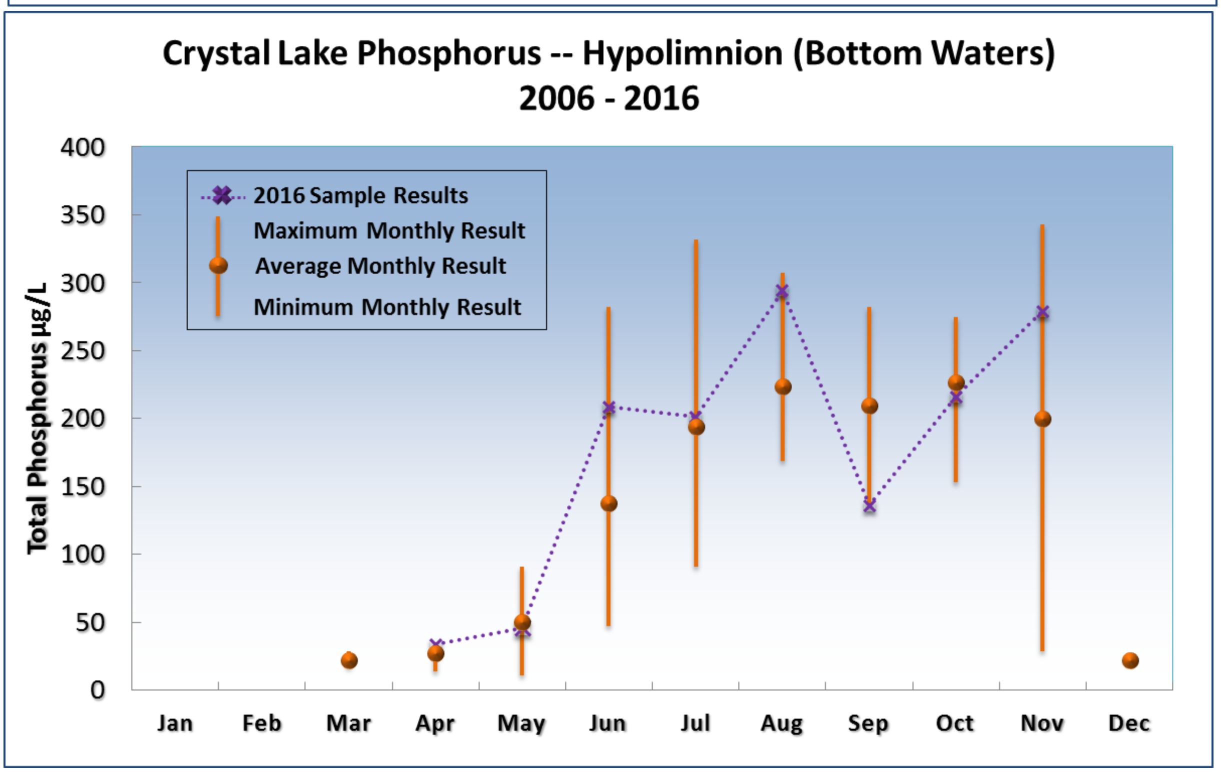


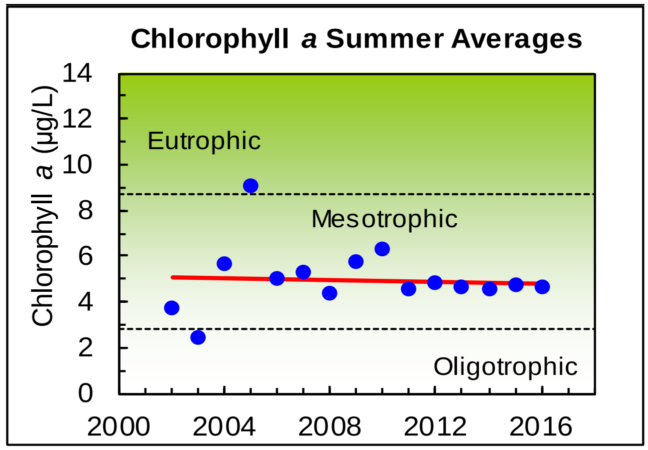


When the lake mixes, phosphorus levels drop because the phosphorus diffuses throughout the lake. This phosphorus remains to feed algae growth in the spring. (Generally, no bottom water samples are collected during the winter when the phosphorus levels are uniform throughout the lake.)

Chlorophyll a (Algae)

Algae are tiny plant-like organisms that are essential for a healthy lake. Fish and other lake life depend on algae as the basis for their food supply. However, excessive growths of algae, called algae blooms, can cloud the water, form unsightly scums, and sometimes release toxins. Excess nutrients, such as phosphorus and nitrogen, are the main cause of nuisance algae growth in a lake. Chlorophyll *a* measurements are one method for tracking the amount of algae in a lake. Chlorophyll *a* is a pigment found in algae and indicates the density of algae in the lake.

Chlorophyll *a* levels in Crystal Lake are moderate, with a long-term summer average of 5.0 µg/L. From 1998 to 2015 there was a statistically significant increase in summer concentrations of chlorophyll *a* (p=0.05), although this trend disappeared in 2016. The previous trend should be viewed cautiously because there were only one or two measurements per year until 2006. The high average of 9.1 µg/L in 2005 was derived from a single June sample. The apparent increase in chlorophyll *a* concentrations is also at odds with the trend toward improving water clarity. However, any increases in phosphorus levels can lead to more algae blooms and higher chlorophyll *a* concentrations.



Wintertime chlorophyll *a* concentrations are typically low, around 1 to 4 µg/L, because of lower algae growth in winter (see figure on page 7). However, during the past nine years of sampling, there have been several springtime spikes in chlorophyll *a* concentrations indicating algae blooms, especially in the month of March. In 2016, the spring bloom occurred in May. These early blooms are likely a result of the high wintertime phosphorus concentrations that result from lake mixing that brings phosphorus from the bottom waters. Also, inflowing water coming from the watershed during rain storms adds more phosphorus. Certain species of algae, including diatoms, are also more likely to bloom in the spring.

Observations at Crystal Lake show that the lake experiences occasional algae blooms that correspond to the higher levels of chlorophyll *a*. A bloom of blue-green algae or cyanobacteria was observed in 2005. Blooms of cyanobacteria are of concern because certain types have the potential to produce toxins. Only minor blooms of blue-green algae have been observed in recent years. However, in some years there have been significant accumulations of stringy filamentous algae growing on the lake bottom that eventually rise to the surface.

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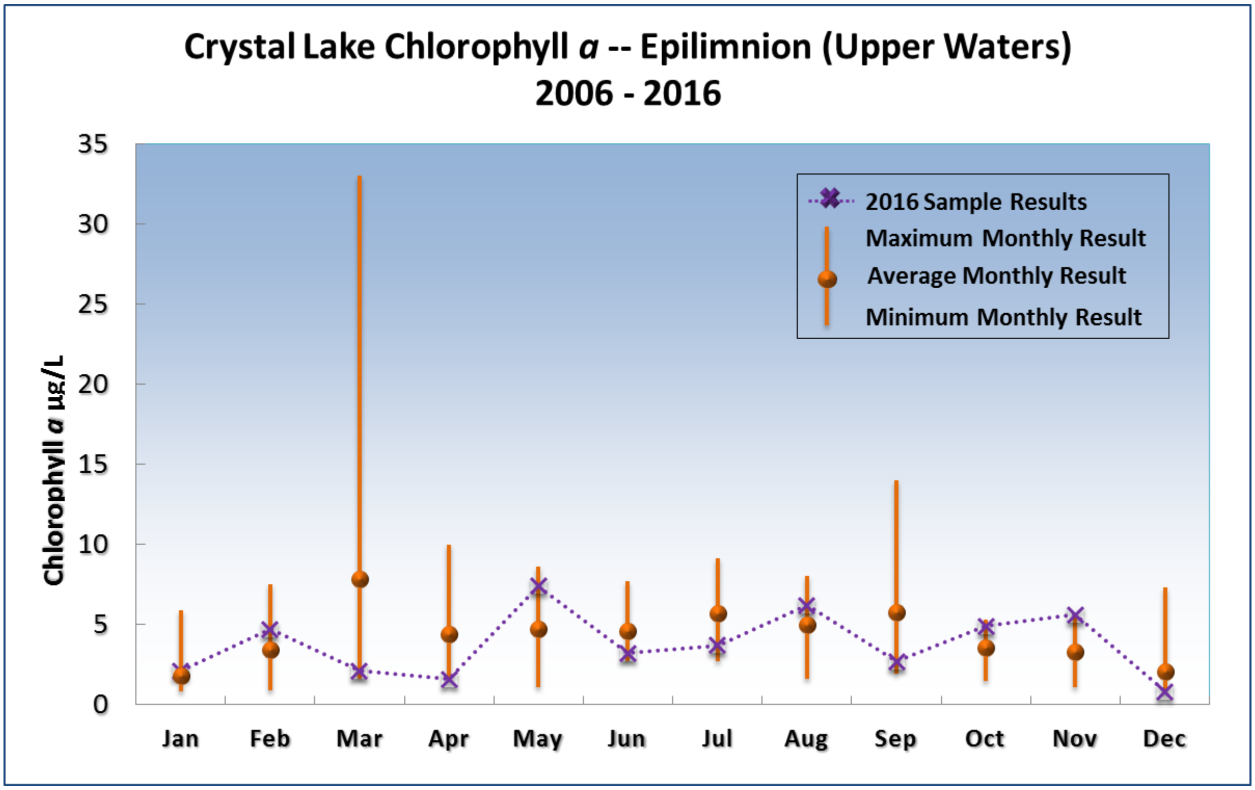

Nitrogen (another essential nutrient for algae)

Nitrogen is another important nutrient for plant and algae growth. Similar to phosphorus, lakes with high levels of nitrogen typically have more aquatic plants and algae. In 2014 - 2015, Crystal Lake had moderate levels of total nitrogen (summer average of 450 µg/L). This is consistent with the moderate chlorophyll *a* concentrations measured in the lake.

The relative abundance of nitrogen and phosphorus can also be a useful indicator of lake conditions. This is referred to as the nitrogen to phosphorus ratio or N:P ratio. When lakes have low N:P ratios (typically less than 20), algae growth is often high and harmful blue-green algae blooms may be a problem. Low N:P ratios may also indicate that fertilizers, septic systems, polluted runoff from developed areas, and release of phosphorus from the lake bottom sediments are contributing most of the nutrients to the lake.

In contrast, when lakes have higher N:P ratios (greater than 20), algae growth will be limited by the amount of phosphorus available, and blue-green algae are usually less of a problem. Crystal Lake's average summer N:P ratio of 31 is moderate. Blue green algae blooms are an occasional problem in the lake.

In-Flowing Streams

Phosphorus is carried into the lake by rain running off from the land in the surrounding watershed. Phosphorus enters the lake either directly from the shore or runs into a stream that feeds the lake. In November 2006, SWM staff collected one set of samples for total phosphorus from multiple locations in the watershed to determine the primary sources of phosphorus inputs. Samples were taken at the north end of the wetland, at 222nd Street, and at three locations along Bostian Road to characterize flow from the Maltby urban area. The results of these samples showed low to moderate levels of phosphorus from all the northern inflows (5 to 26 µg/L).

Since December 2006, inflowing stream samples have been collected only at 222nd Street and at the west inlet of the lake. The 222nd Street location should represent the entire developed area draining into the north end of the wetland, and the west inlet represents the runoff from the mostly forested area to the west of Crystal Lake. Overall, phosphorus concentrations at the 222nd Street inlet averaged 36 µg/L from 2006 – 2017. In the winter of 2016-2017, the 222nd Street inlet averaged 19 µg/L. The west inlet levels have lower phosphorus levels, with a 2006-2017 average concentration of 31 µg/L, and a 2016-2017 winter average of 21.5 µg/L (see figures on page 9).

Although the phosphorus levels in water coming from both the developed and undeveloped areas are low to moderate for most of the wet season, it should be noted that the total amount of phosphorus reaching the wetland and lake may not be low. During periods of high rainfall, it appears that phosphorus concentrations increase as nutrients are flushed from the landscape, as evidence by the high peaks in the 222nd street concentrations during most years, including 2015. This means that the total amount of phosphorus headed toward the lake at those times is high. Even with lower concentrations at other times in the wet season, the total amount of nutrients carried by continuing flows of water is significant. And, because the amount of water coming into the wetland from the developed areas is much larger than the amount flowing into the lake through the west inlet, the total amount of phosphorus from developed areas is higher. However, without actual flow measurements, it is difficult to estimate the total contributions of phosphorus from each area to the lake.

The phosphorus carried by winter flows can take several paths. Some of the phosphorus may be trapped and bound up in the wetland, not immediately reaching the lake. Some may reach the lake and cause immediate effects, such as the algae bloom in March 2007 and the high phosphorus measurement in January 2010. Some may remain in the lake water column to contribute to algae and aquatic plant production during the summer; some may settle to the lake bottom; and some may pass through the lake and be flushed downstream.

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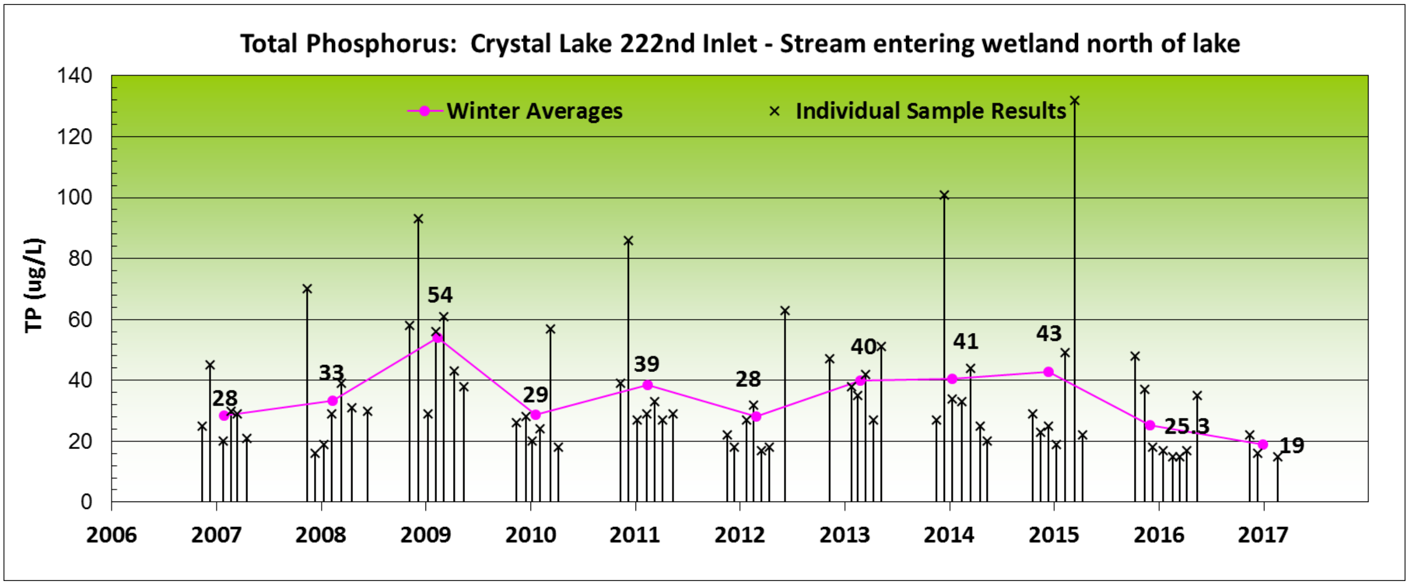

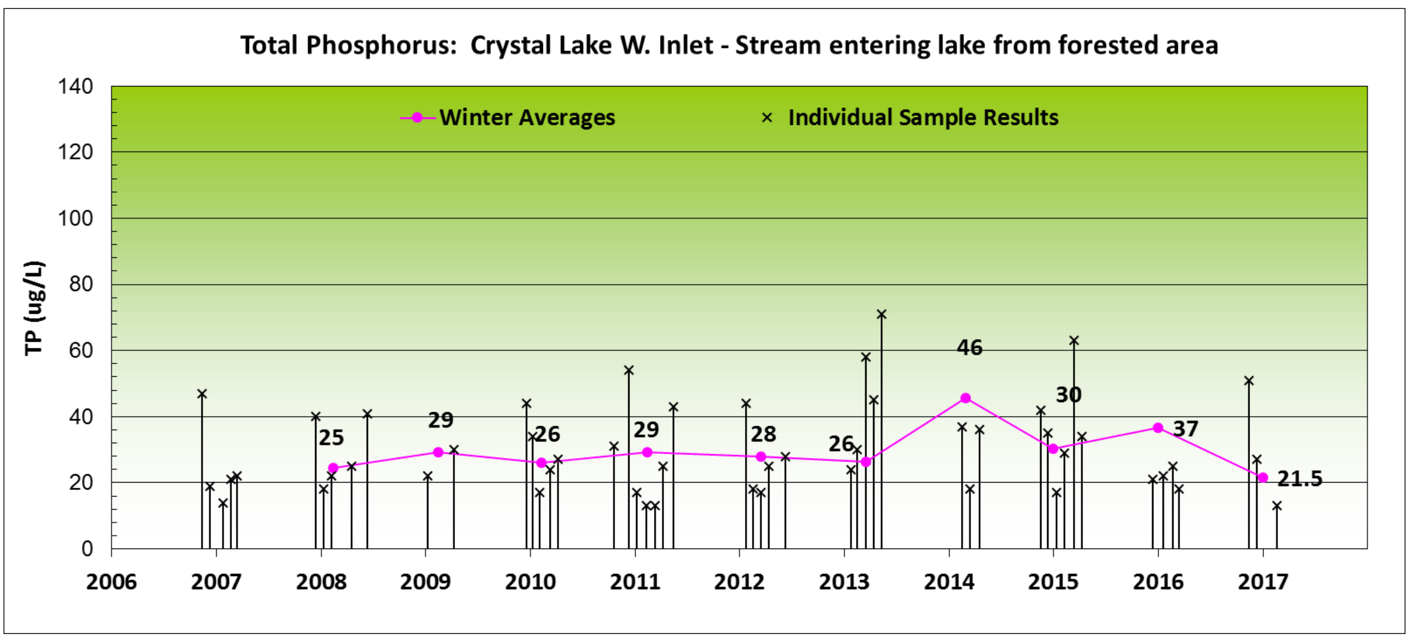

CRYSTAL LAKE

SUMMARY

Trophic State

All lakes go through a process of enrichment by nutrients and sediment. In this process, known as eutrophication, nutrients and sediment contribute to the ever-increasing growth of algae and aquatic plants. Over thousands of years, lakes will gradually fill up with organic matter and sediments.

Lakes can be classified by their degree of eutrophication, also known as their trophic state. There are three primary trophic states for lakes—oligotrophic, mesotrophic, and eutrophic—as well as intermediate states. Oligotrophic lakes are usually deep, with clear water, low nutrient concentrations, and few aquatic plants and algae. Mesotrophic lakes are richer in nutrients and produce more algae and aquatic plants. Eutrophic lakes are often shallow and characterized by abundant algae and plants, high nutrient concentrations, limited water clarity, and low dissolved oxygen in the bottom waters.

The trophic state classification of a lake does not necessarily indicate good or bad water quality because eutrophication is a natural process. However, human activities that contribute sediment and excess nutrients to a lake can dramatically accelerate the eutrophication process and result in declining water quality.

Based on the long-term monitoring data, Crystal Lake can be classified as a meso-eutrophic lake. This means that the lake produces moderate to high levels of plants and algae. The levels of phosphorus (the main nutrient of concern) in Crystal Lake are moderate, while the levels of phosphorus entering the lake/wetland from the principal streams range from low to high depending on rainfall patterns.

Condition and Trends

Overall, Crystal Lake is in fair condition. Water clarity shows signs of improvement. Phosphorus levels in the upper waters appear to be slowly declining. However, phosphorus in the bottom waters may be increasing. In the recent past (1998 through 2015), Chlorophyll *a* values have shown a statistically significant trend toward higher algae growth. In addition, the dense growth of aquatic plants remains a concern for lake users. For these reasons, Crystal Lake appears to be at risk of future water quality declines if increases in chlorophyll *a* levels continue and if phosphorus levels increase, especially in the hypolimnion.

The primary threat to lake water quality is a continuing inflow of nutrients entering the lake or the wetland from new development and human activities in the watershed. Measures to control nutrients in the upper watershed and around the lake shore should be taken to prevent any future negative impacts to the lake. Preservation of the large wetland north of the lake is vital for filtering runoff and protecting the lake from the impacts of upstream urban activities. To find out more about ways to protect lake water quality and information on the causes and problems of increased nutrient levels visit www.lakes.surfacewater.info.

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DATA SUMMARY FOR CRYSTAL LAKE						
		Water Clarity (Secchi depth	**Total Phosphorus (µg/L)**		**Total Nitrogen (µg/L)**	**Chlorophyll *a* (µg/L)**
Source	**Date**	**in meters)**	**Surface**	**Bottom**	**Surface**	**Surface**
Bortleson, et al, 1976	**8/2/1974**	1.8	19	18	-	-
Crystal Lake, Inc.	**6/11/1983**	-	22	-	-	2.3
Crystal Lake, Inc.	**1984**	-	17 - 17 (17) *n = 2*	-	-	0.8 - 2.6 (1.7) *n = 2*
Crystal Lake, Inc.	**9/9/1986**	-	10	-	-	4.7
Crystal Lake, Inc.	**10/6/1987**	-	14	-	-	5.4
Crystal Lake, Inc.	**1998**	-	14 - 23 (18) *n = 3*	-	-	1.0 - 1.6 (1.2) *n = 3*
Crystal Lake, Inc.	**10/15/1990**	-	17	-	-	4
Crystal Lake, Inc.	**8/14/1991**	-	22	-	-	2.5
Crystal Lake, Inc.	**5/15/1992**	-	21	-	-	0.8
Crystal Lake, Inc.	**8/9/93**	-	22	-	-	5.3
SWM Staff	**1994**	1.6 - 2.2 (1.9) *n = 2*	-	-	-	-
SWM Staff	**3/5/1995**	2.1	-	-	-	-
Crystal Lake, Inc.	**1998**	-	16 - 17 (17) *n = 2*			1.1 - 1.1 (1.1) *n = 2*
Crystal Lake, Inc.	**1999**	-	12 - 22 (17) *n = 2*	-	-	0.8 - 4.2 (2.5) *n = 2*
Crystal Lake, Inc.	**9/17/2000**	-	15	-	-	3.2
Crystal Lake, Inc.	**8/8/2001**	-	26	-	-	3.5
Crystal Lake, Inc.	**2002**	-	16 - 23 (20) *n = 2*	-	-	2.1 -5.3 (3.7) *n = 2*
Crystal Lake, Inc.	**5/20/2003**	-	22			2.4
Crystal Lake, Inc.	**2004**		15 - 45 (30) *n=2*	-	-	3.6-7.7 (5.7) *n=2*
Crystal Lake, Inc.	**6/3/2005**	-	25	-	-	9.1

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DATA SUMMARY FOR CRYSTAL LAKE						
		Water Clarity (Secchi depth in meters)	Total Phosphorus (µg/L)		Total Nitrogen (µg/L)	Chlorophyll *a* (µg/L)
Source	**Date**		**Surface**	**Bottom**	**Surface**	**Surface**
Volunteer	**2006**	1.6 - 3.0 (2.1) *n = 11*	15 - 22 (19) *n = 5*	47 - 185 (131) *n = 5*	-	1.9 - 9.1 (5.0) *n = 5*
Volunteer	**2007**	2.2 - 3.6 (2.8) *n = 11*	15 - 22 (18) *n = 6*	106 - 240 (184) *n = 5*	-	1.1 - 7.7 (5.3) *n = 5*
Volunteer	**2008**	2.1 - 3.2 (2.7) *n = 12*	13 - 21 (16) *n = 6*	91 - 275 (198) *n = 6*	-	2.4 - 6.4 (4.4) *n = 6*
Volunteer	**2009**	2.2 - 4.0 (3.0) *n = 10*	13 - 19 (15) *n = 6*	79 - 307 (193) *n = 6*	-	4.0 - 8.0 (5.7) *n = 6*
Volunteer	**2010**	1.7 - 2.6 (2.2) *n = 12*	13 - 23 (18) *n = 6*	38 - 274 (197) *n = 6*	-	1.5 - 11 (6.3) *n = 6*
Volunteer	**2011**	2.2 - 3.9 (3.0) *n = 9*	10 - 24 (15) *n = 6*	29 - 234 (155) *n = 6*	-	2.7 - 6.9 (4.6) *n = 6*
Volunteer	**2012**	1.8 - 3.0 (2.3) *n = 11*	9 - 20 (16) *n = 6*	55 - 262 (189) *n = 5*	-	2.7 - 8.5 (4.9) *n = 6*
Volunteer	**2013**	2.4 - 3.5 (3.0) *n = 12*	12 - 28 (17) *n = 6*	50 - 249 (164) *n = 6*	-	1.6 - 14 (4.6) *n = 6*
Volunteer	**2014**	*2.3 - 3.4* *(2.8)* *n = 11*	*12 - 18* *(14)* *n = 6*	*52 - 332* *(240)* *n = 6*	*52 - 332* *(240)* *n = 6*	*2.9 - 7.5* *(4.5)* *n = 6*
Volunteer	**2015**	*2.4 - 4.0* *(2.9)* *n = 9*	*10 - 23* *(14)* *n = 6*	*11 - 202* *(119)* *n = 6*	*356 - 568* *(428)* *n = 4*	*1.9 - 8.8* *(4.8)* *n = 7*
Volunteer	**2016**	2.3 - 3.4 (2.7) *n = 11*	9 - 20 (13) *n = 6*	46 - 294 (184) *n = 6*	307 - 504 (393) *n = 5*	2.7 - 7.4 (4.7) *n = 6*
Long Term Avg		**2.6** **(1994-2016)**	**18** **(1998-2016)**	**177** **(2006-2016)**	**421** **(2014-2016)**	**5.0** **(1998-2016)**
TRENDS		**Increasing**	**Decreasing**	**None**	**NA**	**None**

NOTES

- Table includes summer (May-Oct) data only.
- Each box shows the range on top, followed by summer average in ( ) and number of samples (*n*).
- Total phosphorus data are from samples taken at discrete depths only.
- "Surface" samples are from 1 meter depth and "bottom" samples are from 1-2 meters above the bottom.